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Request for grant of a patent

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06MAR98 E343361-1 D01091
P01/7700 25.00 - 9804739.2

1. Your reference AA 1395 GB

2. Patent application number *(The Patent Office will fill in this part)* 06 MAR 1998 **9804739.2** RECEIVED BY FAX

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

JOHNSON MATTHEY PUBLIC LIMITED COMPANY
2-4 COCKSPUR STREET
LONDON SW1Y 5BQ

Patents ADP number *(if you know it)* 5362680 01

If the applicant is a corporate body, give the country/state of its incorporation GB

4. Title of the invention

IMPROVEMENTS IN EMISSIONS CONTROL

5. Name of your agent *(If you have one)* IAN CARMICHAEL WISHART

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

JOHNSON MATTHEY TECHNOLOGY CENTRE
BLOUNTS COURT
SONNING COMMON
READING RG4 9NH

Patents ADP number *(if you know it)* 7258312001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* YES

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Patents Form 1/77

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Continuation sheets of this form	0
Description	6
Claim(s)	2 LP
Abstract	1
Drawing(s)	4

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	ONE
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature I C Wishart Date 6.3.98

I C WISHART

12. Name and daytime telephone number of person to contact in the United Kingdom

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AA 1395

DUPLICATE

IMPROVEMENTS IN EMISSIONS CONTROL

The present invention concerns improvements in emission control, and more especially it concerns the control of emissions from diesel engines.

Diesel engines fall into two main categories, namely heavy duty, being principally large engines for trucks, buses and prime mover vehicle engines, ships and boats and stationary engines, and light duty engines, used in smaller trucks and cars. With the increasingly demanding regulation of emissions from all sorts of engines, attention is now being paid to control of emissions such as particulates and NOx from diesel engines. We have, in EP 341,832, described a device marketed as the Continuously Regenerating Trap ("CRT™") by Johnson Matthey. This device traps sooty particulates and causes their combustion by exposing them to NO_2 generated by catalytically oxidising NO present in the exhaust stream. This device has met with considerable success in controlling particulate emissions from heavy duty diesel engines, and can achieve zero emissions of particulate. That is, the CRT as marketed is approximately 100% effective to remove particulates (as defined in the regulations).

We have realised that a conventional CRT may not be cost-effective to control emissions to European Stage III, IV, or higher, regulations from light duty engines. A number of different options for controlling particulates and NOx are available, and engine manufacturers have hitherto favoured engine design and management solutions. There still remains a need for effective systems to meet these emission regulations whilst increasing engine design options.

The present invention provides an emission control system for diesel engines comprising an oxidation catalyst effective to convert a portion of NO in the exhaust gas from said diesel engine into NO_2, and a particulate trap characterised in that at most 85% by weight of the particulates are collected and combusted in the presence of said NO_2 in said trap. According to various embodiments of the present invention, the quantity of particulates collected and combusted may be at most 85%, 60% or at most 50% by weight. It is, however, important that all particulates collected are combusted (over several operating

cycles, but not necessarily over a single operating cycle), in order to avoid accumulation and blocking of the filter, causing build-up of back pressure with consequent degradation of engine performance.

Another embodiment of the present invention comprises an oxidation catalyst effective to convert a portion of NO in the exhaust gas into NO_2 and particle trapping means which means permits a portion of the exhaust gases to escape the trapping means. Desirably, the trapping means is designed to be "fail-safe", that is whilst it is effective to capture 50wt% or more of sooty particulates under normal conditions, the trapping means decreases its collecting efficiency whether by exhaust by-passing the trapping means or otherwise, if the collecting means becomes "saturated" or clogged up. This concept is, we believe, new in diesel exhaust treatment systems.

In the invention, the particulate trap, or trapping means, is designed to be less than 100% effective, and desirably this brings several advantages, the first of which is considerably reduced back pressure. Light duty diesels are less capable of coping with back pressure from exhaust gas systems than heavy duty diesels, because they tend to be of smaller capacity and power.

The present invention is also intended to cater for some of the problems that can arise in practical usage of light duty diesels. If such engines are used in small cars or vans which are used at low speeds in towns for large portions of their operations, the exhaust gas temperature tends to be quite low, perhaps not more than 100-120°C. Under these conditions, although sooty particulates are generated in less quantities than under heavy load, the temperature is below that for the most efficient oxidation of NO to NO_2 and hence there can be insufficient NO_2, or the reaction temperature is too low, for effective combustion of the sooty particles. Accordingly, for many vehicles for much of the time, the trapping means should collect sufficient of the particles to meet the emission regulations, but using a design that collects such particulates for subsequent combustion when conditions are improved, and permits the exhaust gas to pass through without excessive back pressure. In such systems,

at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycles are improved.

It will be recognised that the prime purpose of the invention is to remove a proportion only of the particulates from the exhaust gas stream. This is intended to be adequate to meet the appropriate emission regulation when combined with engine design and management improvements. The reduced efficiency of the present invention brings about a significant reduction of cost, however, from a reduced volume and weight for both the catalyst and the trap compared to the state of the art CRT designed for such an engine.

The oxidation catalyst may be any that is effective to convert sufficient NO to NO_2, and is suitably a high platinum loading catalyst carried on a ceramic or metal honeycomb catalyst support. It is envisaged that in addition to reducing volume and weight of the catalyst, savings may be made in precious metal loading, thus reducing the cost yet further.

The particulate trap may suitably be a woven or knitted wire mesh or perforated metal or a suitable ceramic material. The trap is suitably designed for each individual engine design, because the particulate emissions differ significantly from engine to engine. The trap may, but need not, carry a catalytic coating intended to initiate combustion at lower temperatures.

A preferred embodiment of the present invention combines the emission control system with NOx control means. The NOx control may be achieved in a number of ways including exhaust gas recirculation, using a NOx conversion catalyst downstream of the trap or, more preferably, combining the trap system with a NOx absorbent. Such NOx absorbents are known to those skilled in the art and may utilise an alkaline earth metal oxide such as baria or calcia or other suitable materials. Together with the trap system of the present invention, such an absorbent can permit extremely useful control of emissions, for example up to about 80% removal of particulates combined with up to about 80% removal of NOx. The NOx trap is desirably a single through-flow canister, which may be regenerated by periodic enrichment of the exhaust gas in a number of ways. In an even more

preferred embodiment, the trap system of the invention is combined with a lean-NOx catalyst and a NOx trap. A particularly desirable embodiment is where the NOx trap is effective to trap the NOx at low temperatures and releases NOx at higher temperatures, *eg* about 250°C, at which temperatures NOx may more readily be converted and/or used in the particulate combustion of the present invention.

When using the presently-preferred platinum-based catalyst, the present invention should be used with fuel of not more than 50ppm sulphur, and preferably below 50ppm sulphur, more preferably below 10ppm sulphur. Other catalyst systems may have a wider range of fuel sulphur levels.

The invention may be better appreciated by reference to the accompanying drawings, in which:

Figure 1 is a schematic cross-section of a first embodiment of the invention,
Figure 2 is a schematic cross-section of a second embodiment of the invention, and
Figure 3 is a schematic cross-section of a further embodiment of the invention, and
Figure 4a is a schematic cross-section of a yet further embodiment, and
Figures 4b and 4c are cross-sections along the lines A-A and B-B of Figure 4a.

Referring to Figure 1, a canister is to be mounted in the exhaust system of a light duty diesel, *eg* a 1.9 litre Tdi engine. The canister, 1, contains an oxidation catalyst, 2, which is a platinum catalyst carried on a 100cells/sq in metal honeycomb substrate. Particulate passes through the catalyst. A perforated gas distributor, 3, is mounted downstream of the catalyst, and surrounding the gas distributor is a sintered stainless steel filter, 4, which is located centrally within the canister. It can be seen that it is possible for the exhaust gases to by-pass the filter if the filter becomes clogged. Under ideal conditions, the filter collects sooty particles which are continuously combusted in the NO_2 generated by the catalyst, according to one or more of the equations:

$$NO_2 + C \rightarrow NO + CO$$
$$2NO_2 + C \rightarrow 2NO + CO_2$$
$$2NO_2 + 2C \rightarrow N_2 + 2CO_2$$
$$NO_2 + O_2 + C \rightarrow 2NO + CO_2$$

Under non-ideal conditions, that is at low exhaust gas temperatures, a portion only of the particulate is collected in the filter, and most of the exhaust gas by-passes the filter. Returning to higher exhaust gas temperatures permits the combustion reaction to re-start and the particulate can be totally removed from the filter.

Referring to Figure 2, an embodiment is shown which permits substantial accumulation of particulate without by-pass, but using a filter, 5, which is not 100% effective. The same items as in Figure 1 are identified using the identical reference numerals. There is sufficient capacity to accumulate particulate under all normal operating conditions.

Figure 3 utilises a slightly different by-pass design to that of the embodiment of Figure 1. The particulate is collected by impingement on a baffle plate, 6, and is shown by mass, 7. The baffle plate may itself be porous to gas or act as a filter. As exhaust gas temperatures rise, the hot gases immediately contact the collected particulate and quickly cause combustion. This design may comprise electrical heating of the collection area on plate 6, creating a hot spot to initiate combustion. In a further design variation the baffle plate may comprise upstanding walls, giving a U-shaped cross-section.

Figure 4a shows a development of the embodiment of Figure 3. Gas leaving catalyst 2 deposits sooty particles on the face, 7, of a machined and plugged ceramic or steel monolith, 8. The gas then passes through a machined passageway, 9, before impacting on the directly opposing face, 10, of the monolith. The gas then must turn and pass through a second passageway, 11, before being discharged. Such a design provides a low back-pressure trap which is effective to remove more that 50wt% of particulate matter. As the

conditions alter, primarily as gas temperatures reach 250°C or more, NO_2 formed in the catalyst is effective to combust the accumulated sooty particulate matter.

It will be appreciated that there are many possibilities to vary the designs shown without departing from the principles of the present invention.

CLAIMS

1. An emission control system for diesel engines, comprising an oxidation catalyst effective to convert a portion of NO in the exhaust gas from said diesel engine into NO_2, and a particulate trap, characterised in that at most 85wt% of the particulates are collected and combusted in the presence of said NO_2 in said trap.

2. A system according to claim 1, wherein an exhaust gas by-pass is provided so that a portion of the exhaust gas does not pass through the filter.

3. A system according to claim 2, wherein said by-pass is effective only when substantial trapping of unburnt particulates has occurred.

4. A system according to claim 2, wherein said by-pass is effective under all operating conditions and at least 50wt% of particulate matter is trapped and combusted.

5. A system according to any one of the preceding claims, arranged such that at least 50wt% of particulate matter is trapped and subsequently combusted when operating conditions in the same or subsequent operating cycle are improved.

6. A system according to any one of the preceding claims, in combination with NOx control means.

7. A system according to claim 6, wherein the NOx control means comprises a NOx absorbent.

8. A system according to claim 7, wherein said NOx absorbent is effective to trap NOx at relatively low exhaust gas temperatures, and releases NOx when the exhaust gas temperature exceeds about 250°C for conversion and/or consumption in the combustion of particulate matter.

9. An emission control system for diesel engines substantially as hereinbefore described.

10. A method of controlling emissions, especially particulate matter, from diesel engine exhausts, comprising passing said exhaust through an oxidation catalyst to convert NO to NO_2, trapping at most 85wt% of particulate matter in said exhaust gas and combusting said trapped particulate matter by the NO_2.

11. A method according to claim 10, comprising using an exhaust gas by-pass such that at least 50wt% of particulate matter is collected and combusted.

12. A method according to claim 10, substantially as hereinbefore described.

IMPROVEMENTS IN EMISSIONS CONTROL

Abstract of the Invention

A cost-effective solution to removing particulates from diesel, especially light-duty diesel, engines incorporates an oxidation catalyst (2) effective to convert NO in the exhaust from the engine to NO_2 and a particulate trap (4) which traps no more than 85% by weight of the particulate, optionally by permitting gas to by-pass the trap.

(Figure 1 to be used)

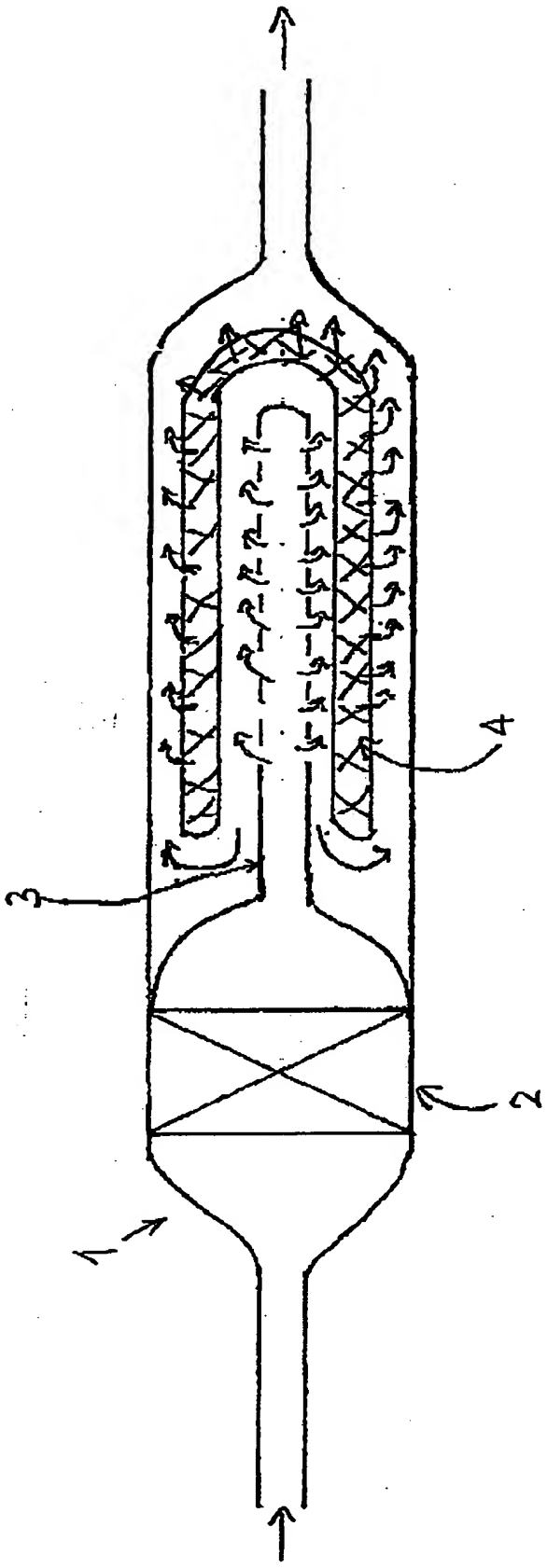

Fig 1

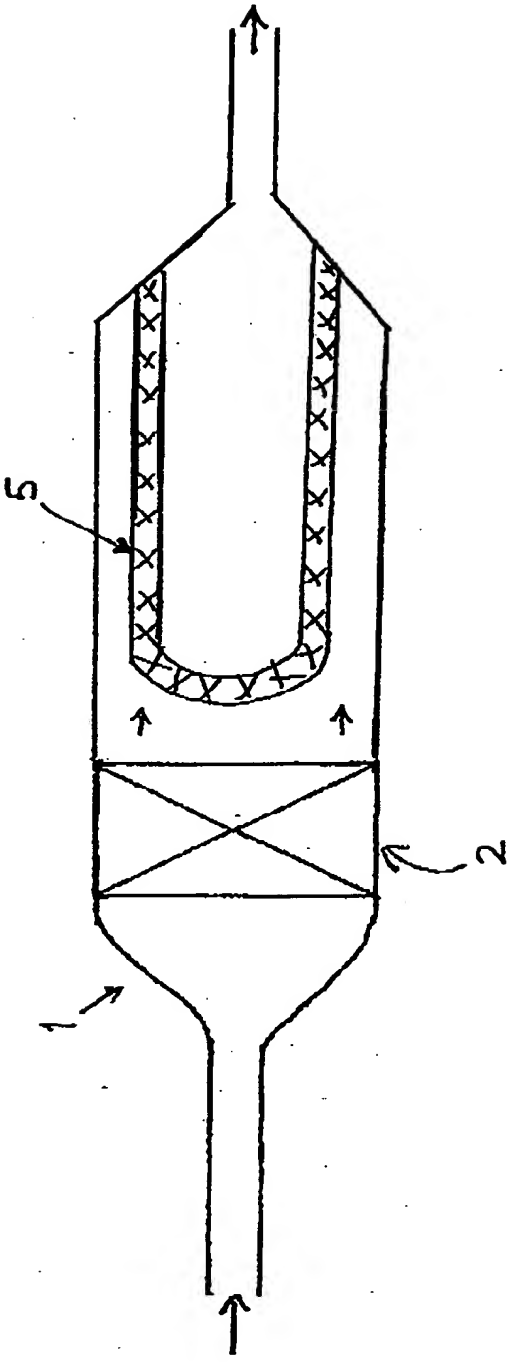

Fig 2

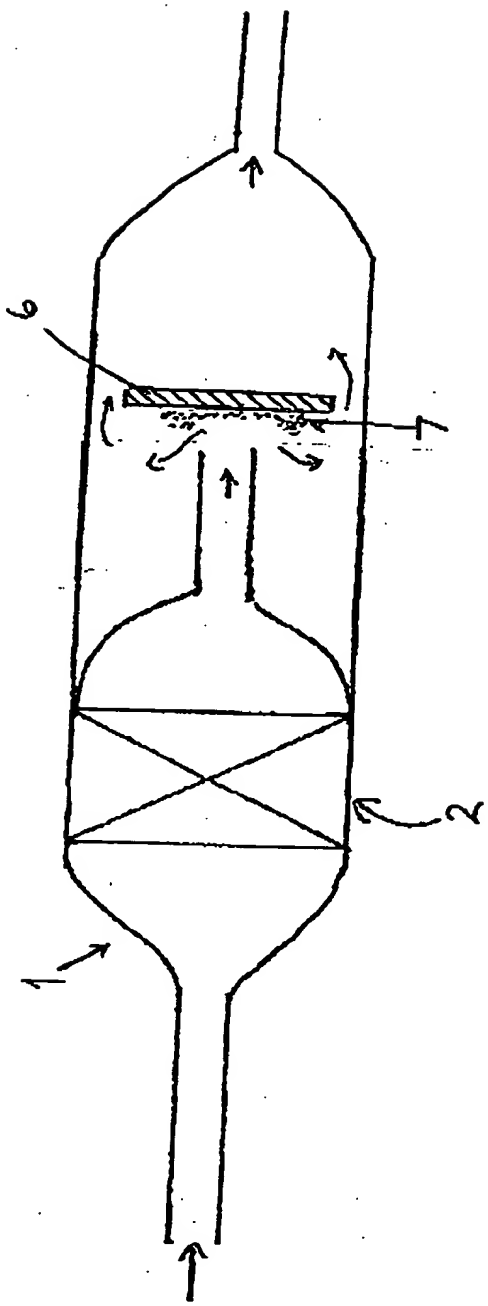

Fig 3

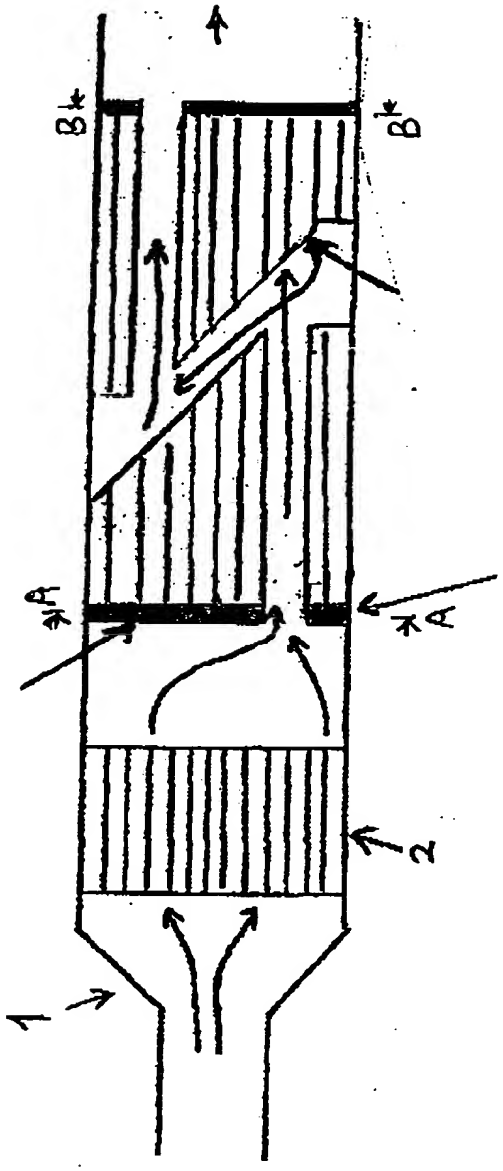

Fig 4a

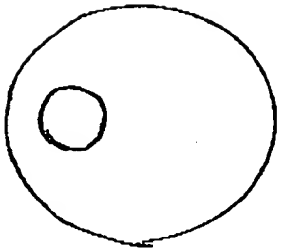

Fig 4c

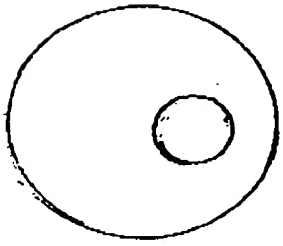

Fig 4b

PCT/GB99/00626

Johnson Matthey plc.

4/3/99